DIFFERENTIAL ROTATION OF CORONAL HOLES

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Abstract. Using KPNO helium 10830 Å synoptic charts of Carrington rotations 1716 through 1739, and by assembling a time sequence representing single latitude zone, rotational properties of coronal holes for five zones of latitudes ($\pm 10°$, $\pm 20°-\pm 40°$, and $\pm 40°-\pm 60°$) have been examined. It seems that the rotation period of coronal holes is a function of latitude, thus reflecting differential rotation of coronal holes.

1. Introduction

The sunspots, the photospheric magnetic fields, filaments and the photospheric gas itself all suffer differential rotation as a function of latitude (cf., e.g., Newton and Nunn, 1951; Howard and Harvey, 1970; Wilcox and Howard, 1970). Some features for instance sector boundaries and certain coronal structures observed in green line λ5303 Å appear to rotate as rigid bodies (Wilcox and Tannenbaum, 1971; Svalgaard, 1972; Antonucci and Svalgaard, 1974). Coronal holes observed in Fe XV λ284 Å and in soft X-rays also demonstrated 'almost rigid' rotation (Wagner, 1975; Timothy *et al.*, 1975).

It is difficult to understand how the holes can manifest rigid body rotation when the magnetic fields with which the holes are associated are expected to undergo differential rotation. Therefore, rotational properties of coronal holes have been investigated to probe the validity of the 'almost rigid' rotation of coronal holes.

2. Observational Data

The KPNO helium 10830 Å synoptic charts (which are expected to have a close correspondence with the emission from the coronal holes (cf. Harvey *et al.*, 1975)) of Carrington rotations 1716 through 1739 taken from the *Solar-Geophysical Data* are used for this study. We divided these synoptic charts into limited zones of latitudes ($\pm 10°$, $\pm 20°-\pm 40°$, and $\pm 40°-\pm 60°$) and assembled time sequences for various latitude zones. Figures 1–5 represent these time sequences of the five latitude zones centred on the equator and on 30° and 50° latitudes in each hemisphere.

3. Results and Discussion

The strong regularity of coronal holes in longitudes and their long lifetimes are immediately apparent from Figures 1–5. This very qualitative picture may be analogous to Bumba and Howards' results on certain new patterns like rows and streams in the large-scale distribution of solar magnetic fields (Bumba and Howard, 1969). Figures 1–5 display coronal hole rows (CH rows) and coronal hole streams (CH streams). A

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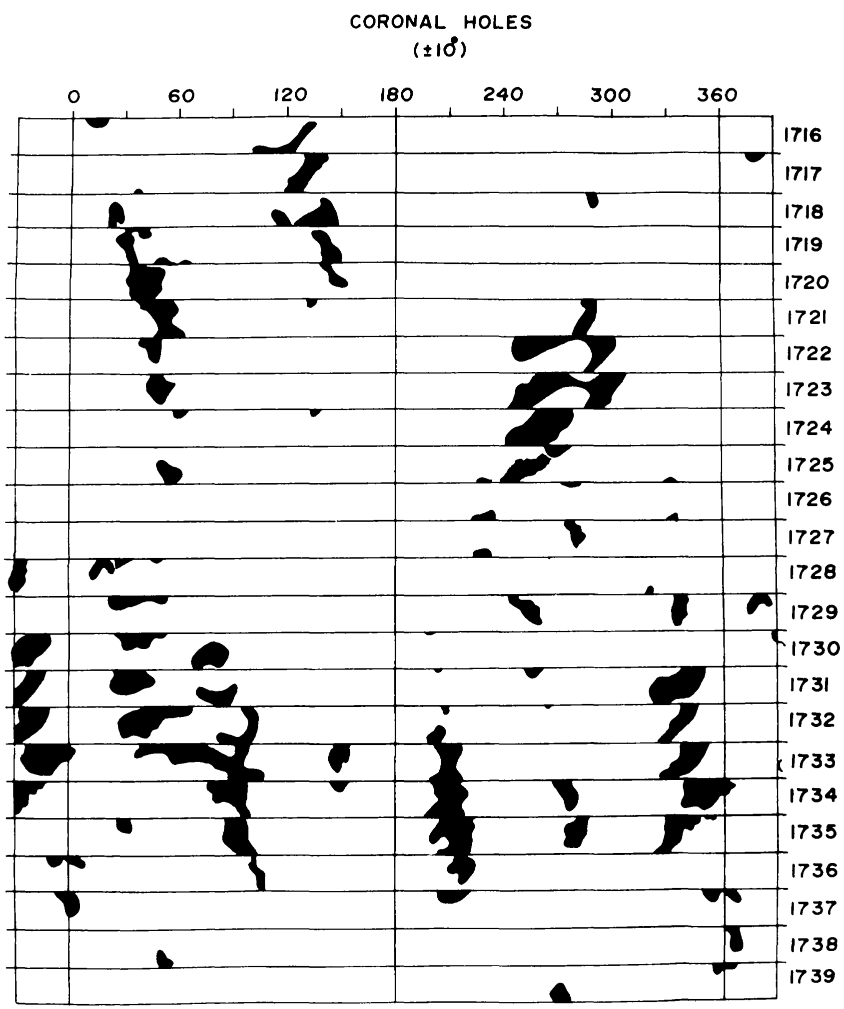

Fig. 1.

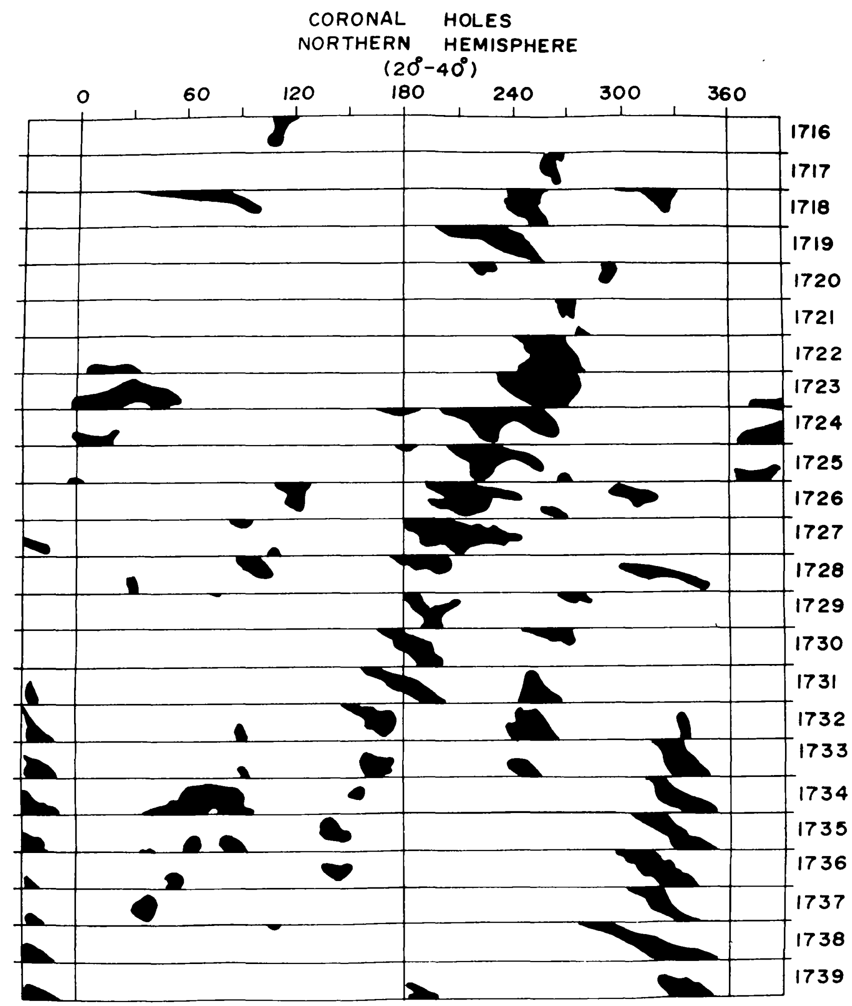

Fig. 2.

Figs. 1–5. Coronal hole synoptic charts cut into strips representing five zones of latitude (± 10°, ± 20°–± 40°, and ± 40°–± 60°) and assembled in chronological order. The dark regions represent the coronal holes.

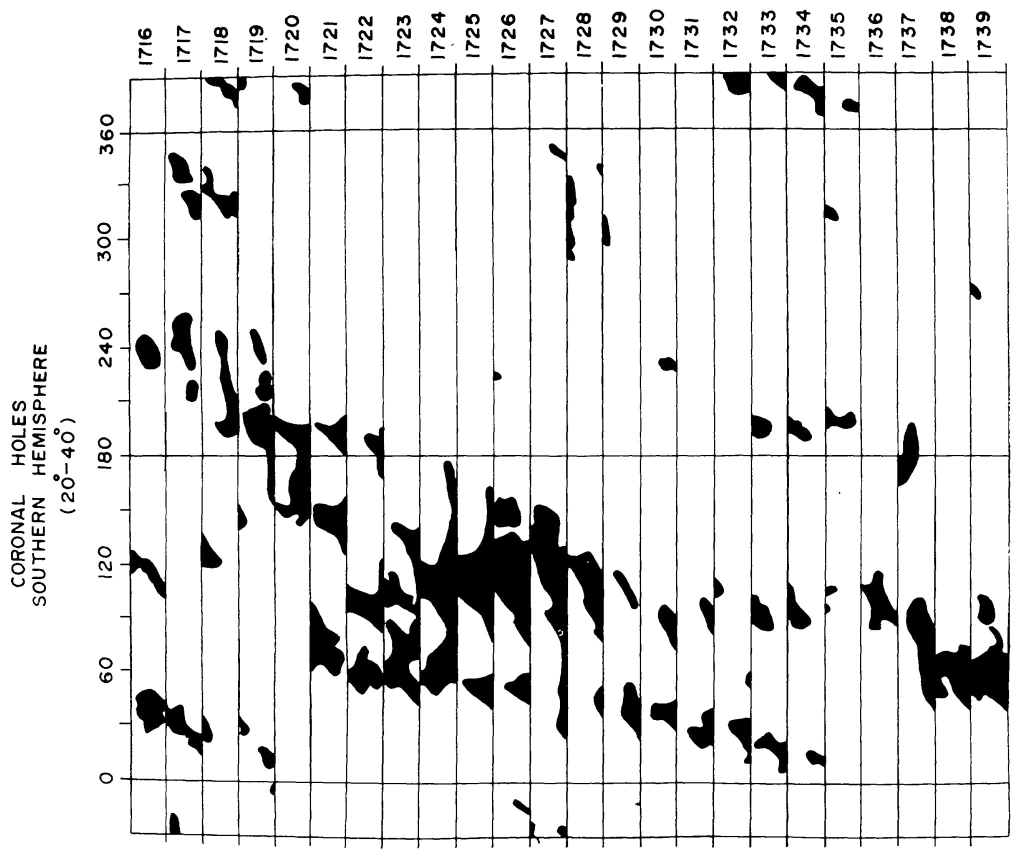
CORONAL HOLES
SOUTHERN HEMISPHERE
(20°-40°)
0
60
120
180
240
300
360
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739

Fig. 4.

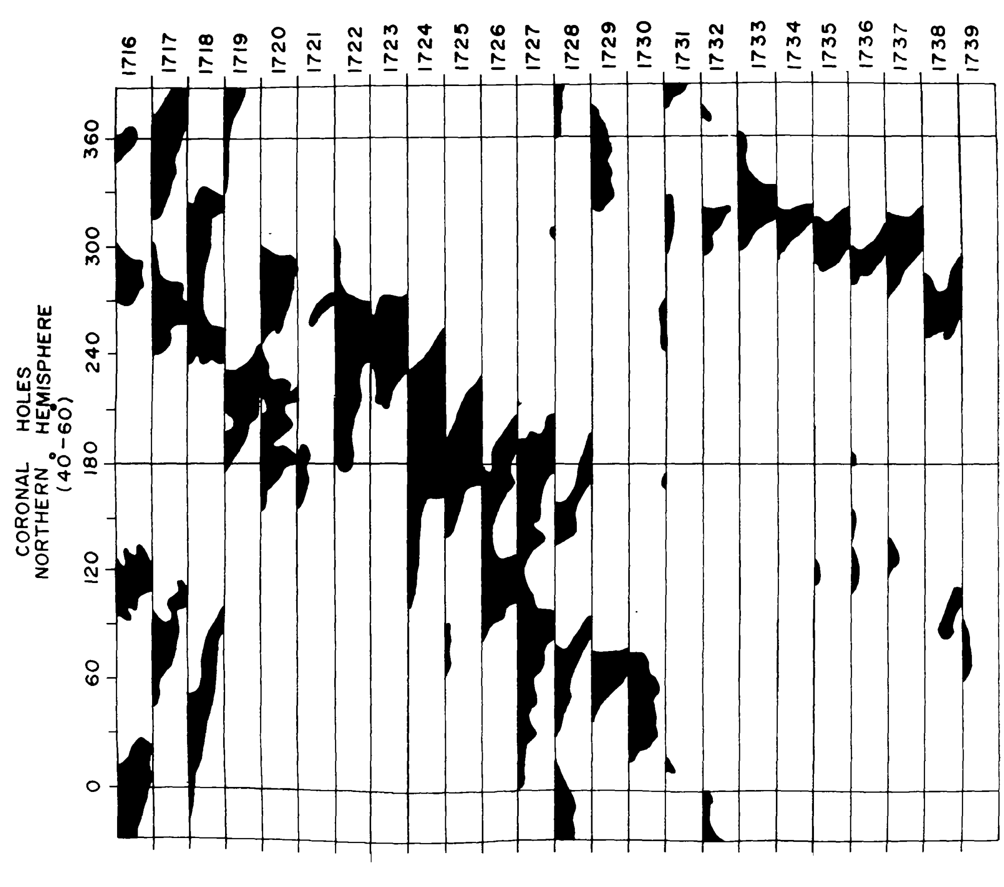
CORONAL HOLES
NORTHERN HEMISPHERE
(40°-60°)
0
60
120
180
240
300
360
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739

Fig. 3.

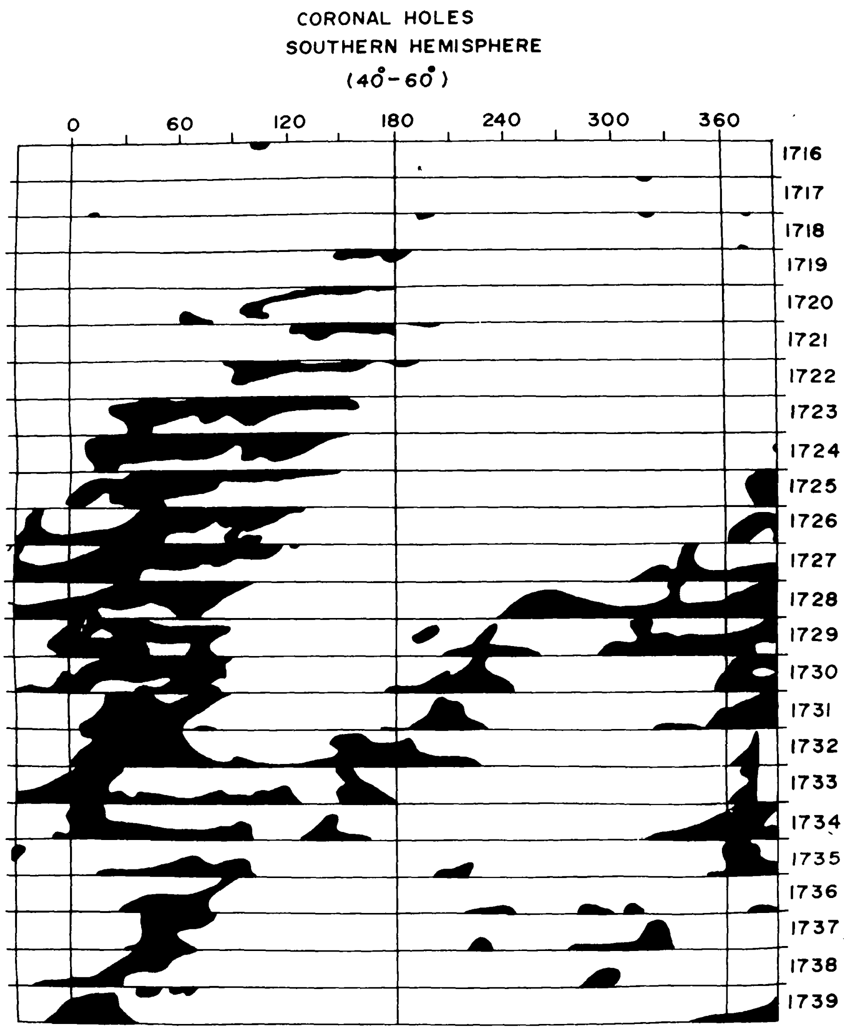

Fig. 5.

sequence of coronal hole sections on consecutive synoptic maps assembled in chronological order form a CH row, whereas a very long CH row or several CH rows constitute a nearly continuous CH stream. There are at least three CH streams in equatorial zone (Figure 1), with beginning at longitudes 30°, 120°, and 270° at rotations 1718, 1716, and 1722, respectively. In 20°–40° north latitude zone one very long and well-defined CH row, constituted by sections of single coronal hole may be identified at longitude 290° and rotation 1720 which can subsequently be followed up to rotation 1736 (Figure 2). In higher latitude zone at 40°–60° north, there is a long and broad continuous CH stream at longitude 300°–360° at rotation 1716 (Figure 3). This stream may consist of a grouping of CH rows and can be followed even after rotation 1731, when the rough position of the CH stream is 310° longitude at rotation 1732. In southern hemisphere at 20°–40° south latitude zone (Figure 4) a long and complex CH row with beginning at 240° longitude and rotation 1716 and followed until longitude 20° and rotation 1734 is seen. From a comparison of Figures 4 and 5, it is clear that this CH row is formed out of the sections of a single broad coronal hole. In Figure 5, there are two CH rows at longitudes 200° and 260° at rotations 1718 and 1728, respectively.

It is apparent from Figures 1–5 that sections of coronal holes seem to drift westward (with respect to Carrington longitude) in the equatorial zone and eastward in higher latitude zones ($\varphi > 10°$), reflecting differential rotation of coronal holes. If the CH rows or CH streams were not inclined to the vertical, it would indicate a rotation of Carrington period of exactly 27.3 days. It is clear, however, that nearly all the CH rows and CH streams are inclined. In equatorial zone ($\varphi = \pm 10°$), CH rows are slightly inclined to west by about 5° per rotation which means that the coronal holes in the equatorial zone have their recurrence period close to 26.9 days.

In higher heliographic latitudes in northern and southern hemispheres ($\varphi = 20°$–$40°$ and $40°$–$60°$) the CH rows or CH streams drawn in Carrington's co-ordinates are inclined in opposite direction if compared with equatorial CH rows or CH streams and their inclination angle is greater. The inclination angles are about 10° and 20° per rotation for latitude zones of 20°–40° and 40°–60°, respectively. These inclinations seem to be connected respectively with about 28.0 and 28.8 days synodic rotational period of the hole sections developed in those latitude zones.

The zonal rotation periods of coronal holes as a function of latitude thus determined show that the coronal hole sections at higher latitudes rotate slower than that the hole sections at equatorial zone. This indicates that the rotation period of coronal holes is a function of latitude and thus exhibits a differential rotation of coronal holes.

4. Conclusion

Based on the observational data of Carrington rotations 1716 through 1739, we conclude that the coronal holes observed in helium 10830 Å exhibit differential rotation which is not in consonance with the conclusions drawn by Wagner (1975) and Timothy *et al.* (1975).

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